TECHNOLOGY DEPARTMENT

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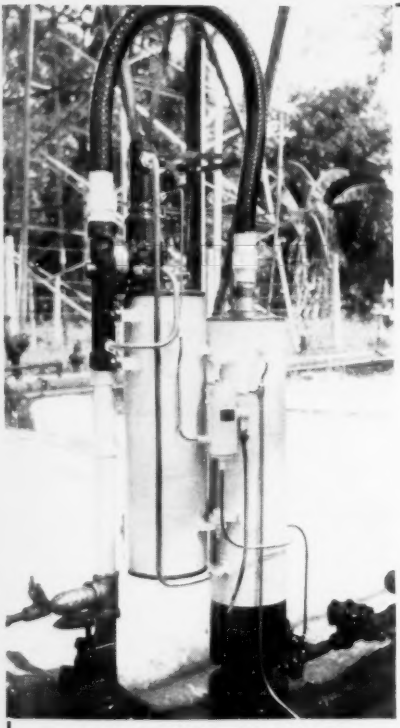

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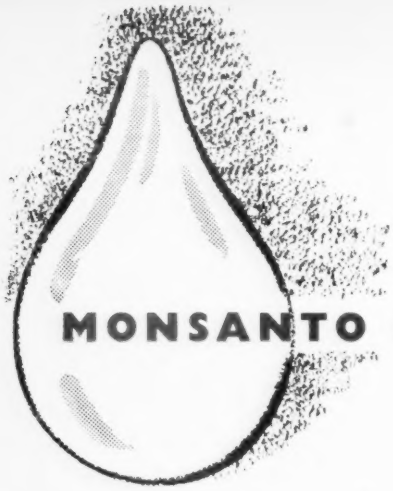

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No. 38 FEBRUARY 1950 Vol. 4

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## CALCULATING PETROLEUM RESERVES

*By* G. M. LEES (Fellow)

The United States has contributed 64 per cent of the world's total production of petroleum and is currently producing 59 per cent. It would seem that it has achieved some modern form of widow's cruse in that, year by year, the total of its proved reserves continues to grow notwithstanding production on a massive scale. The statements, so frequently quoted, that the U.S. has only 13 years or so of supply in sight must seem perplexing to non-geological minds, as the qualification is not usually added that the figures published yearly by the American Petroleum Institute refer only to proved reserves. No estimate is attempted of the possible reserves still to be found, and clearly the current discovery rate indicates that the total reserves must be substantially greater than the proved. But by how much, and how accurate are the estimates of proved reserves anyhow? And can the U.S. experience of productivity be applied to other sedimentary areas elsewhere in the world?

The amount of oil in place in any oilfield can be calculated with reasonable accuracy provided data on the porosity of the reservoir rocks and the connate water content are known, but assumptions creep in between the esti-

mates of oil in the ground and of oil in the tank. A recovery factor must be assumed, and this can vary between 20 and 80 per cent, depending on the nature of the drive, whether by gravity drainage, by gas expansion or by water drive ; and nature can be substantially assisted in many cases by "secondary recovery" methods—gas repressuring, injected water drive or, in the extreme case, by oil sand mining. The efficiency of recovery is closely affected by economic factors and geographical situations. In a protected market, for example in the Wietze field in Germany, it is profitable to mine oil sands already exhausted by ordinary production methods and to achieve a 100 per cent recovery, but as far as one can reasonably anticipate the future it is unlikely that such an extreme recovery method will be generally applied and, at any rate, only to certain shallow fields in favourable conditions.

The yearly figure of the proved reserves of the U.S.A. is a carefully prepared estimate based on all known factors and making reasonable assumptions for percentage recovery. A new discovery well is only credited with a modest reserve of 40 acres in its immediate vicinity and additions to the field are added yearly as its total extent is indicated by extension wells, with the result that the figures given are firmly proven with a minimum of speculation. The recovery factor is probably the greatest unknown. An increase in the price of crude can extend the lives of small "stripper" wells and can make secondary recovery methods profitable in marginal cases—and a fall in price can lead to the abandonment of small wells and even of old fields which, once abandoned, may never be re-equipped. But, all in all, the published figures give a fair measure of proved reserves, and the U.S. total at end 1948 was 26,821 million barrels (*I.P. Review*, 1949, **3**, 145) or thirteen years' life at the current production rate.

In 1948 the American Petroleum Institute formed a Sub-Committee on long-term availability of crude oil, and their report (*Petrol. Engr*, July 1949, page 936) shows that, as a result of their study, they are confident that the U.S. supply can be maintained at about 50 per cent above its current rate for the coming five years and probably for five subsequent years. After that they are non-committal, but they seem to anticipate a slow decline in the following years with increasing contributions from synthetic oil produced from natural gas and from solid fuels. The natural gas reserves in the U.S. are approximately equal in thermal value to those of the proved oil reserves.

Various estimates of the total reserves, i.e., proved plus possible, of the United States have been made in the past by Arnold, Wallace Pratt, G. C. Gester, and others, and, while the results differ widely, there seems little likelihood that new discovery will equal past production plus present proved reserves ; perhaps as much as two-thirds of the total oil has already been found. There is no possible means of arriving at any accurate basis for such an estimate and at best it is only an intelligent guess. Various attempts have been made to relate oil reserves to the cubic mileage of sediments in which the oil has been formed. The United States is the only country in the world which has been sufficiently intensively explored and developed to allow a yard-stick to be extracted for comparison with other countries where exploration is still at an early phase. Some years ago I attempted a study on these lines. I analysed the various producing areas, or in some cases whole states, in the U.S., to arrive at a figure of productivity per square mile (I abandoned an attempt to include the third dimension), and I got the following results for (a) past production and present proved reserves, and (b) estimated total ultimate production:—

| State | | (a) (Tons per sq. mile) | (b) (Tons per sq. mile) |
|---|---|---|---|
| California | Total State | 8,300 | 10,200 |
| California | Oilfield basins only | 132,000 | 162,000 |
| Oklahoma | Total State | 12,700 | 17,000 |
| Texas | Total State | 10,500 | 21,000 |
| Louisiana | Total State | 7,000 | 14,000 |
| Kansas | Total State | 3,750 | 6,000 |
| Illinois | Total State | 3,300 | 4,000 |
| Pa.—West N.Y. | Selected area | 3,100 | 3,500 |
| Arkansas | Total State | 2,700 | 3,500 |
| Montana | Basin areas | 300 | 900 |
| Wyoming | Basin areas | 1,800 | 3,600 |
| Colorado | Basin areas | 140 | 700 |
| New Mexico | Basin areas | 1,600 | 2,400 |

Two generalizations can be drawn from these figures: first, that there are some local areas of exceptional oil-richness, and in the U.S. the Californian oil-bearing basins make a striking contrast to other areas; and secondly, that most areas having reasonable thickness of sediments, say at least 5,000 to 10,000 feet and fulfilling certain structural desiderata, have a prospect of oil productivity of about 9,000 tons per square mile on average, though admittedly it is difficult to average such a range of figures.

The United States oil discovery experience straddles such a wide range of structural conditions and stratigraphical ages that it is reasonable to apply it to other countries now less intensively explored. The U.S. success in the past has not been because of unique endowment by nature but as a consequence of intensity of exploration effort. Where a country is small, for example Britain, a comparison may not be fair, but where an extensive area with a wide diversity of geological circumstances is involved, a comparison should be valid.

Various estimates of the possible total reserves of the world have been made by oil geologists after a study on similar lines but again the results differ very widely. Wallace Pratt holds the high field with his estimate ("Oil in the Earth," 1942) of 100,000 million barrels for U.S.A. total ultimate production from 1,200,000 sq. miles. This implies a productivity factor of approximately 12,000 tons per sq. mile, and he has extended his estimates to other countries with similar optimism. In 1946 J. Terry Duce (*Petrol. Times*, 1946, **50**, 382) applied Pratt's productivity figure for the U.S.A. to a global estimate of prospective areas abroad, which he gave as 4,800,000 sq. miles, and so got a world reserve, excluding U.S.A., of 55,000 million tons, of which only 6,000 million tons were then estimated as proved.

Such estimates are, of course, really only intelligent guesses. The oil-richness of various petroleum provinces varies within great limits, but when an overall productivity factor is applied to extensive areas, over-estimates in one locality may be compensated by under-estimates in others. In my opinion the U.S. productivity factor may be too high for general application to countries with unfavourable geographical situation, at any rate if by reserve we mean the amount of oil which will be discovered and won and not the total amount existing in the ground. An area like the headwaters of the Amazon or the Antarctic continent will have a geographic handicap for as far into the future as it is possible to see at present, and the intensity of search will of necessity be less than in more favoured regions. My figure for oil productivity of the U.S. is 9,300 tons per square mile compared with Pratt's 12,000, but for estimating elsewhere in the world perhaps 5,000 would be a more realistic figure.

Estimates of prospective areas in the world vary within equally large limits based on personal evaluation of the extent of effective sedimentary areas in countries with inadequate geological exploration. The country containing the greatest uncertainty is the U.S.S.R., both European and Asiatic. The area covered by sedimentary rocks with possible prospects is approximately 1,000,000 and 3,000,000 square miles in European and Asiatic U.S.S.R.

respectively ; and if a figure of 5,000 tons per sq. mile is assigned to the former and 3,000 to the latter, the possible reserves amount to 5,000 and 9,000 million tons, or a total of 14,000 million tons, of which only 860 million have been produced to date. In 1937 Goubkin published estimates of the oil reserves of the entire Soviet territory, with separate figures for proved, semi-proved, and speculative possibilities ; his total figure for all categories being 6,376 million tons. His estimates were much criticized at the time, largely owing to the lack of any acceptable standard to assign to a calculation of speculative reserves and yet, if American experience of productivity is applied, his estimate appears modest. The oil-richness of the Baku district is exceptional and one is not justified in supposing that another area of similar productivity will be found. The Apsheron Peninsula, which contains the Baku group of fields in an area of only about 180 sq. miles, had yielded 342 million tons by 1937 and if the proved reserves as then estimated (123 million tons) are added, the productivity factor becomes 2,600,000 tons per square mile. This figure may, of course, be fictitious to the extent that the drainage area which supplied the oil may extend into the Caspian Sea far beyond the limits of the peninsular itself.

The proved reserves of the Middle East oilfield province have recently been estimated by DeGolyer and MacNaughton ("Twentieth Century Petroleum Statistics," 1949 Edition) as follows :—

| | | |
|---|---|---|
| Kuwait . . | 10,950 | million barrels |
| Saudi Arabia . | 9,000 | ,, ,, |
| Iran . . . | 7,000 | ,, ,, |
| Iraq . . . | 5,000 | ,, ,, |
| Total . . | 31,950 | ,, ,, |
| or . . | 4,260 | million tons. |

The basis for these estimates has not been stated but clearly the figures are not comparable in accuracy with those of the proved reserves of the U.S. The Burgan oilfield of Kuwait has a sandstone reservoir and the oil in place can be calculated, but the remaining fields have limestone reservoir rocks and both the total oil in place and the percentage recovery of limestones are notoriously difficult to estimate. Assuming that DeGolyer's estimates give an approximation to reality, they refer to proved reserves only and not to total possible. The Middle East oil province has a possible area of about 700,000 sq. miles ; but it is unlikely to be uniformly prolific, and some areas may be relatively barren—Syria, for example, has not yet responded to exploration treatment. DeGolyer's estimated proved reserves, if related to the total area of 700,000 sq. miles, give a productivity factor of 6,100 tons per sq. mile, but clearly the total reserves must be several times those already proved. Various estimates of the proved plus possible reserves have been made—J. E. Pogue (*Oil Gas J.*, 3.8.46, page 59) for example, estimated 24,000 million tons, which would give a productivity factor of 34,000 tons per sq. mile—but naturally these must be regarded as guesses rather than estimates based on any degree of knowledge. The size of individual oilfield units in the Middle East is so big that the productivity over such an immense area seems to be unique and so standards from experience elsewhere in the world may not be applicable.

Other petroleum provinces in the world can be similarly estimated, but I have indicated sufficiently the degree of uncertainty which is inevitable in making these estimates. One point, however, emerges clearly from any such survey of possible world reserves, namely, that the oil supply will continue to meet the world's demands for many decades to come, perhaps even for a century or more. The world's demand in, say, 50 years' time is perhaps as uncertain as

is any guess of the size of world reserves. In comparison with coal, the petroleum reserves are extremely small, but on the whole we need have no anxiety for the power resources for future generations.

*Postscript*

Since completion of this article, I have received the paper by A. I. Levorsen on "Estimates of Undiscovered Petroleum Reserves," contributed to the United Nations Conference on World Resources (August 1949). Levorsen has achieved fame by producing the biggest ever estimate of the world's oil reserves at 200,000 million tons, or 500 years' supply at current production rate. In the discussion on his paper there was a general chorus of disbelief and by general consent this estimate should not be accepted as reasonable. Two thirds of Levorsen's total amount is attributed by him (on the authority of Wallace Pratt) to the continental shelves of the world ; but this, of course, is based on a fallacy. The continental shelves of a continent are only the extension seaward of the land mass and, if the adjacent dry land is barren of any oil prospects, there can be no expectation from its submerged extension seaward. Throughout the world as a whole, there are only limited sectors of continental shelves with any prospects at all and still fewer with sufficiently high grade expectation to overcome the physical handicap. If Levorsen were right we should make a start in selectively breeding web-footed oil men for the oil-winning of the future.

* * *

## EMPIRE MINING CONGRESS

It has been announced that the Proceedings of the Fourth Empire Mining and Metallurgical Congress, held in Great Britain in July 1949, will now be published at £2 for the two volumes instead of £2 per volume. Enquiries should be sent to 436 Salisbury House, Finsbury Circus, London, E.C.2.

## SULPHUR (CORROSIVE)-COPPER STRIP TESTS

I.P.—64/49

The text of paragraph 1(b) of the Introduction to this method, as printed in the Tenth (1949) Edition of "Standard Methods for Testing Petroleum and Its Products," unfortunately contains errors.

Users are asked to note that this paragraph should read as follows:

> "(b) It is suggested that Procedure A should be used for motor fuel, kerosine, gas oil and diesel fuel, Procedure B for lubricating oils, and Procedure C for white spirits."

* * *

## SOUTH WALES DINNER/DANCE

On Wednesday, October 26, 1949, coinciding with the meeting of the Branches Committee of Council, the South Wales Branch of the Institute held a dinner/dance at the Seabank Hotel, Porthcawl.

This, the first event of its kind to be held by the Branch, resulted in an enjoyable evening being spent by members and invited guests. The toast "Our Guests" was proposed by E. Thornton, Chairman of the Branch, and responded to by H. Hyams, a vice-president of the Institute.

The toast to the South Wales Branch was given by W. C. Robertson, of the United States, in charge of the Badger constructional operations at N.O.R. Ltd., Llandarcy. This was supported by A. W. Taylor, of the Welsh Engineers and Founders Association, responded to by R. B. Southall, general manager of the National Oil Refineries Ltd.

Members of the Branches Committee and their ladies were guests of the South Wales Branch and included representatives from London, Stanlow and Birmingham.

# COUNCIL COMMENTARY

Twenty-one members of the Council welcomed back the President to the chair at their meeting of December 14, 1949, and the Minutes of the previous meeting were very quickly approved and signed. Two matters only which needed further attention arose from these: encouraging response from Member-Companies with regard to their subscriptions being reported by the General Secretary, and the date of February 2 for the Social Evening.

Passing to new business, Mr R. B. Southall presented the Report of Branches Committee, which had met last in Wales. It was recommended that specific financial grants be made to the Birmingham Students Branch, rather than that they should be supported by capitation fees. He asked Mr Hyams, who had been present at the last meeting of the Branches Committee to report on suggestions for altering methods of financing branches in the future. Mr Hyams stated that, on account of the tendency to 100 per cent corporate membership in certain branches, it was now desirable to fix a maximum sum which could be donated by Council to all the Branches, and leave the proportioning of this to the Branches Committee. An amount was agreed for the 1950 allocation.

The Public Relations Committee then made recommendations with regard to the arrangements for the Annual Dinner and also for a new drive for increased corporate membership.

Mr Hyams, on behalf of the Finance Committee, outlined a Staff Pension scheme, which met with approval and which is to come into force in January 1950. The General Secretary expresssed thanks on behalf of the staff for this scheme.

The vexed question of income-tax liability was again discussed and further suggestions put forward tentatively. These had to await the written advice from the solicitors before being made final.

Mr Hyams also raised the question of the idea of starting a building reserve fund, but it was decided after brief discussion to leave this matter until the 1949 accounts were available.

Mr Pracy then presented a report of the Election Committee, drawing attention to certain resignations, which were dealt with individually, and also to the desirability of qualified members in the Associate grade being transferred to full Membership Fellowship grades. The proposals for new elections were approved.

The By-laws Committee report was presented by Mr Biske, who indicated that, following a further meeting in January, definite proposals would be made for a revised By-law 65.

* * *

## THE ANNUAL DINNER

There will be three toasts at the Institute's Annual Dinner at the Savoy Hotel, on February 28, 1950. After the toast of "The King", The Rt. Hon. Lord Llewellin, P.C., C.B.E., M.C., T.D., will propose the toast of "The Institute of Petroleum" and the President, Mr E. A. Evans, will reply. The toast of "The Petroleum Industry" will be proposed by Sir William Palmer, K.B.E., C.B., President of the Oil Consumers Council. Sir Frederick Godber, Chairman of the Shell Petroleum Company, will reply.

* * *

**Scientific Film Census.**—Although the Scientific Film Association has information from over four hundred scientific film makers and agencies, it is believed there are still many whose names and films are known only to a limited sphere. Information required is title of film, its gauge, its length, maker's name and address, and a brief synopsis. Details from the Secretary, 4 Great Russell Street, London, W.C.1.

# MY VISIT TO AMERICA

*By* THE PRESIDENT

Of course I enjoyed it. Had it been otherwise my mission must have been a failure.

I went at the invitation of the A.S.T.M., the S.A.E., and the A.P.I. The relations of our own Institute with the A.S.T.M. have been getting closer and closer because we have so much in common. We have had the pleasure of welcoming to London representatives of the A.S.T.M. in the persons of Burroughs, Detwiler, Sherman, and Tuemmler in the last year or two. They have brought us greetings and have done much to win our affection and admiration. The time came when the A.S.T.M. wished to express its good wishes to the I.P., so it invited its president to the meeting at San Francisco.

On my arrival in New York, the Shell, Jersey, and Texas companies almost took possession of me. It was embarrassing, but very delightful. At San Francisco, Howard Vesper, president, of California Research Corporation acted as my guide, and friends at Shell, Emeryville, were very attentive. President Morrow of A.S.T.M. of course gave me the official welcome. Mr Warwick, executive secretary, planned a programme which enabled me to meet the maximum number of members. At the official luncheon I was the guest speaker. My technical education was improved by the meeting, and my appreciation of the welcome I received everywhere and from everyone was very sincere. The desire of the A.S.T.M. to work with the I.P. is obvious, and I do hope that we shall do all we can to demonstrate to the world what can be achieved by this co-operation.

My visit to the S.A.E. meeting at St Louis had the purpose of forming a triangular friendship between the S.A.E., the I.P., and the Automobile Division of the Institution of Mechanical Engineers. This was possible because I am the vice-chairman of the Automobile Division. President Sparrow manifested the true spirit of camaraderie. Mr John Warner is a well poised host and understands the value of unity.

The A.P.I. meeting at Chicago was a bit bewildering. Between five and six thousand petroleum men from all over the United States require a good deal of marshalling into their respective sections. Yet the whole thing went like clockwork. The organization was magnificent. The large number of meetings I attended filled me with admiration for their decorum and technical ability. As might be expected the social activities were plentiful. At a meeting of this size it would be difficult I suppose, to have an official dinner, but I was invited to the luncheon of the Board of Directors and sat between the president of Shell and the president of Gulf.

In these brief words I have tried to convey an impression of the warmth of my welcome and the admiration the petroleum industry and the automotive industry in the United States has for its fellow thinkers and workers in Great Britain. I am sure it is sincere. May we treasure it and enlarge it.

## THE A.S.T.M. LUNCHEON

During the course of his speech at the A.S.T.M. petroleum industry luncheon Mr Evans said: Those of us who have striven on both sides of the Atlantic for a close collaboration between the A.S.T.M. and the I.P. must be very proud that the wooing has been so successful. We can and should encourage the rest of the world to adopt the standard methods for testing petroleum upon which our two societies have agreed.

*The handshake of friendship between President Morrow of the A.S.T.M. and President Evans of the I.P.*

He looked forward to many years of happy co-operation, continued Mr Evans, and a state of perfection, which would admit of no inferior ingredient, must be built up. There were no major differences between them and what minor differences did exist could be eliminated by tolerance and liberality.

Among the pleasant things of life, said Mr Evans, were the visit to England of Messrs Burroughs, Detwiler, Sherman, and Tuemmler, who had done so much to endear the A.S.T.M. to the I.P. They had done yeoman service with Mr Hyams and his colleagues in finalizing the complicated subject of measurement of oil in bulk.

Concluding, Mr Evans said: An enthusiastic co-operation sets the pace of development, consequently, there must always be a feeling of participation when either of us is considering new problems or new standards. Whether we shall ever reach that ideal which is an instant of perfection made infinite—the best of the best for ever, depends upon you and us.

## THE S.A.E. BANQUET

Speaking at the banquet of the S.A.E., Mr. Evans said it was pleasant to think of the gallery of great men who had invented and achieved noble things in the automotive and petroleum worlds. But they must not forget that the progress of the internal combustion engine might be due also to an almost too plentiful supply of cheap petroleum.

The motor car is a manifestation of years of patient development and costly research. In England research arrangements were somewhat different from those in America. Co-operation must be international. There was a great measure of understanding between American and British petroleum companies. The petroleum industry and automotive industry are so interdependent that they must, and do, work for their common good. Concluding, Mr Evans said: Your president can do much to foster a friendship with those of us in England who are receptive, but it is up to all of you to do your part.

* * *

Since his return to England, the President has received expressions of appreciation in letters from C. L. Warwick (*executive secretary, A.S.T.M.*), from S. W. Sparrow (*president, S.A.E.*), and from J. A. C. Warner (*general manager, S.A.E.*). Extracts from these letters follow:

"*Your participation in the technical sessions dealing with high-additive content oils and turbine oils, and in the various sessions of our Committee D-2 on petroleum products and lubricants, was most welcome; but even more we enjoyed your splendid and most appropriate remarks as the guest speaker at the Petroleum Industry Luncheon, as well as your participation in the several social events that gave a number of us the opportunity of making your acquaintance and discussing with you topics of mutual interest to the Institute of Petroleum and A.S.T.M.*

"*Indeed, your most welcome visit has, I am sure, served in many ways further to cement the fine co-operative relations between our two organizations, which are substantially promoting important technical developments in the petroleum industries of our two countries.*" C. L. Warwick.

*"We of the Society of Automotive Engineers want you to know how much we appreciated your presence with us and to have you bring friendly greetings as president of the Institution of Petroleum and as vice-chairman of the Automobile Division of the Institute of Mechanical Engineers. Please convey to your British colleagues an expression of our sincere admiration and good will."* S. W. Sparrow.

*"Better understanding and closer co-operation between our two great nations, and between the technical interests that we represent, surely will result from your visit."* John A. C. Warner.

★ ★ ★

## "FLUID HANDLING"

The first issue of this new monthly is dated December 1949 and it is stated that it is "devoted to those engaged in the problems set by the diverse operations associated with fluids, whether liquid, solid or gaseous and however difficult their handling may be."

In this first issue there are articles on tetra cresyl silicate for heat exchange, on the pumping of sludges (*by M. B. Donald*), on the launching of the undersea pipeline at Lutong, on the handling of corrosive fluids (*by B. N. Reavell*), on proportiometer pumps at the plant of Petrochemicals Ltd. (*by G. J. E. Howard*). In addition, there are many other items of interest in the 44 quarto pages of text. The journal is well illustrated and the line diagrams are noteworthy for the clarity of their lettering.

Cost for a year's subscription is 20*s* (25*s* overseas) and it may be ordered from the publishers, the Binjon Press, 33 South Audley Street, London, W.1.

★ ★ ★

**Electrical Resistance Alloys.**—A brochure sets out in tabular form the characteristics and properties of the Red Fox range of electrical resistance alloys. Requests for copies should be addressed to Samuel Fox and Co. Ltd., Stocksbridge Works, nr Sheffield, or to the Publicity Dept., The United Steel Companies Ltd., 17 Westbourne Road, Sheffield, 10.

## SOUTH WALES BRANCH

At Britannic House, Llandarcy, on November 4, 1949, W. C. Sydenham, delivered a lecture entitled "A survey of accident prevention in industry."

Mr Sydenham, who is a senior safety engineer to the Anglo-Iranian Oil Company Ltd., dealt first with the functions of a safety department, particularly in an oil refinery, and led up to regulations, protection of personnel, plant and equipment, and the planning of a safety and accident prevention programme.

He stressed the importance of accident statistics for expressing frequency and severity rates and the analysis of records and detailed reports as aids in accident prevention.

Charts were shown giving data collected over a number of years on hourly, daily, and seasonal incidence. With E. S. Squire in the chair, an interesting discussion followed, particularly on the evaluation of loss of man hours due to accidents.

On December 1, 1949, at Britannic House, Llandarcy, A. W. Jarman, of the Mexphalte Department of Shell-Mex & B.P. Ltd., delivered a paper entitled "Bitumen Horizons." This was in part a repeat of that given recently to the parent body in London (*J. Inst. Petrol.*, 1950, **36**, 1-12).

In his very interesting and illuminating paper Mr Jarman did not deal with the manufacture or testing of bitumen, but confined his remarks to the uses, grouped under the headings of road and industrial.

He described the development of the different methods used in the preparation of road surfaces. In dealing with the industrial uses, he surprised many of his listeners by referring to the varied and numerous examples. He also considered aspects of the usage and relation to physical properties. In the discussion which followed Mr Jarman dealt with all questions in a very capable manner.

# SIGNIFICANCE OF PROPERTIES OF PETROLEUM PRODUCTS

## VIII. SULPHUR CONTENT

*By* C. V. HILL (Fellow)

Most crude petroleums contain sulphur compounds in varying proportions. These compounds can impart unpleasant odours to some products, can be corrosive in others, and may affect colour stability and lead response. Even those sulphur compounds which are not directly objectionable are potentially so, since on combustion they become converted to sulphur oxides which are corrosive in the presence of water. Generally speaking, therefore, sulphur is an undesirable constituent of petroleum products although it is often present in a sufficiently innocuous form to render its removal unnecessary, while in a few instances the presence of sulphur actually appears to be beneficial.

If a sulphur-bearing crude is distilled under low temperature conditions, it is frequently possible to obtain light distillates which are substantially free from sulphur. Under normal distillation conditions, however, such light distillates from sulphurous crudes contain compounds such as hydrogen sulphide, thio-ethers, disulphides, polysulphides, mercaptans, and thiophenes. Most of these compounds appear to be derived from the decomposition of heavy complex sulphur bodies originally present in the crude, and it has been shown that in the neighbourhood of 130° C, a definite decomposition occurs in the crude which causes sulphur to appear in the distillates. In addition to these sulphur compounds, sulphur may occur in the elemental form due to the aerial oxidation of hydrogen sulphide, a reaction which takes place readily in the presence of moisture. Distillates containing $H_2S$ are therefore given a chemical treatment at an early stage to remove the $H_2S$ before it has time to be oxidized to elemental sulphur.

Because of the importance that sulphur assumes in the petroleum industry it is not surprising that a number of methods of test have been developed for estimating its presence or its effect. The I.P. standard methods of test include a corrosion test for lubricating greases (112/48T), $H_2S$ content (103/47T), mercaptan sulphur content (104/45T), residual odour of lacquer solvent (89/44P), sulphur content (61/49, 62/42, 63/42T, 107/45T), corrosive sulphur in distillates (64/49), corrosive sulphur in motor fuel (65/42). In addition, the literature contains many references to the effect of sulphur and its removal or conversion.

Each class of petroleum product is differently affected by the presence of sulphur compounds according to the use to which the product is to be put. Thus, petroleum gas will contain only $H_2S$ and methyl mercaptan, since these are the only two sulphur compounds which boil in this particular temperature range. Apart from the objectionable feature of forming sulphur dioxide and sulphur trioxide on combustion, both are corrosive to copper and some other metals which may be used in systems handling petroleum gases. It is, therefore, usual to remove $H_2S$ completely and reduce the total sulphur content of the gas to below 0.05 per cent by weight before it is sold as a fuel.

### *Gasolines and Spirits*

In the case of motor and aviation gasolines the boiling range of approxi-

mately 0°C to 200°C is much wider, and the number of sulphur compounds which can occur is much greater. The lower boiling mercaptans have an offensive odour and are either removed or oxidized by mild reagents to the less odorous disulphides. This oxidation process is known as sweetening and does not normally result in reducing the total sulphur content of the fuel. Elemental sulphur and polysulphides are both corrosive and the refiner endeavours to ensure that they are not present. On the other hand, sulphides and disulphides are generally considered inoffensive. Nevertheless, they are technically undesirable as they have the effect of reducing the octane number which can be obtained by the addition of a given amount of tetra-ethyl lead. Thiophene is the exception to this rule, and has practically no effect on lead response. It may however react with T.E.L. in the presence of oxygen and cause a white precipitate to appear in the leaded aviation gasoline—an undesirable effect which can be obviated by the addition of an inhibitor. Many sulphur compounds have a depressing effect upon the rich mixture rating of aviation gasoline so that the sulphur content of this product is often reduced to a very low order. This high sensitivity to the presence of sulphur led to the development of a test (I.P. 107/45T) which is capable of determining sulphur contents as low as 0.0001 per cent.

White spirit and special boiling point spirits are other products which are sensitive to sulphur. Where these are used as solvents in the production of perfume and edible oil it is essential that they should be free from the odour associated with the presence of sulphur compounds, and where they are used as thinners for paints they must be free from any sulphur compounds which will react with the pigments. Where white spirit is used for dry cleaning, the presence of unstable sulphur compounds may lead to odour reversion, i.e., gradual souring in use of a spirit which was initially without odour, with a subsequent transference of the odour to the clothes. For such products it is usual to specify a very stringent copper corrosion test (B.S. 245:1936).

*Kerosine*

In the kerosine or burning oil boiling range, a large variety of sulphur compounds are possible, but those which concern the refiner are mercaptans, disulphides, polysulphides, and elemental sulphur. Mercaptans have an objectionable odour and are therefore sweetened, i.e., converted into disulphides which have a relatively sweet odour. In carrying out this process the refiner must make sure that he does not produce elemental sulphur or polysulphides by side reactions, since these compounds are not only corrosive but tend also to spoil the burning properties of the kerosine. The total sulphur content must also be reduced to a reasonable figure to ensure that the oxides of sulphur formed during burning do not reach objectionable proportions in a living room where the lamp or heater is used. In power kerosine used for agricultural tractors, etc., sulphur is less injurious, and this product can contain a higher total sulphur content than either lamp kerosine or motor fuel.

*Diesel Fuel*

The effect of sulphur in diesel fuel is at present under intensive investigation, and is the subject of considerable controversy. It has been shown that under carefully controlled laboratory conditions tests can be carried out to show that sulphur has the effect of increasing both wear and deposits in a diesel engine. These results have, however, been criticized on the grounds that the test did not represent service conditions, and it is claimed that many naturally sulphurous fuels do not show increased wear in service. There would appear to be no satisfactory method of settling the

argument except by prolonged trials in a fleet of diesel-engined vehicles under service conditions using naturally sulphurous and non-sulphurous fuels.

*Fuel Oil and Bitumen*

Heavy fuel oils from various crudes contain widely varying contents of sulphur compounds, the characters of which are almost completely unknown. The principal objection to high sulphur content in fuel oils is that combustion produces large volumes of sulphur-acids which contaminate the atmosphere of large industrial towns. Corrosion of the top of the chimney stack may also occur if the temperature of the gases falls below their dew point. In certain industries, such as steel and glass manufacture, high sulphur fuels are undesirable since part of the products of combustion may be absorbed into the melt with consequent degradation of the stock.

The sulphur content of bitumen is usually quite high, and may reach 5 to 7 per cent in some cases. The type of sulphur compounds is not known, but it appears likely that much of the sulphur may be combined in the asphalt micelle. There is no direct evidence that sulphur in bitumen is objectionable.

*Lubricants*

It is believed that the presence of sulphur in lubricating oil may in some cases be beneficial, and some authorities claim that if a lubricating oil is refined for the complete removal of sulphur compounds, lubricating properties are seriously reduced. Cutting oils, and also certain lubricants used under extreme pressure conditions, have elemental sulphur deliberately added in order to corrode the bearing surface and produce a sulphide film of high load-bearing capacity. Other products in the lubricating oil range are the technical white oils and paraffin wax. These are heavily refined to improve both odour and taste, since they are frequently used in edible preparations. Although it is not certain that the unpleasant taste and odour caused by inadequate refining is due to sulphur compounds, the intensive refining treatment removes the sulphur.

In conclusion it would be not unfair to say that the petroleum refiner generally has a wider knowledge of the good and bad effects of sulphur in his products than the individual user ; and the refiner, by adjusting his process to give satisfactory products, automatically shields his customers from much of the knowledge which comes from experience.

## Suggestions for Further Reading


*Crude Oils and Distillates*

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"Determination of types of sulphur compounds in petroleum distillates." *U.S. Bur. Mines Rep. Invest.* R.I.3591, Dec. 1941.
(This publication has an extensive bibliography.)

"Boiling points, freezing points, densities, and refractive indices of some sulphur compounds in petroleum." *U.S. Bur. Mines Rep. Invest.* R.I. 4060, Dec. 1946.

*Motor and Aviation Fuels*

"The effect of sulphur compounds on octane number of leaded fuels." Part 1. "Comparison of different sulphur compounds," H. K. Livingston, *Oil Gas J.*, 11.3.48, **46** (45), 80-7; 20.1.49, **47** (38), 67.

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*Lubricating Oils*

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*Diesel Fuels*

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"The Chemical Constituents of Petroleum," A. N. Sachanen, New York, 1945.

"The Conversion of Petroleum," A. N. Sachanen. New York, 1940.

"The Chemical Refining of Petroleum," V. Kalichevsky and B. Stagner. New York, 1942.

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## OIL AND THE DOLLAR DRAIN

The following statement was issued by the Ministry of Fuel and Power on December 20, 1949.

There is now under discussion between the Governments of the United States and the United Kingdom the problem of the dollar drain on the U.K. and the rest of the sterling area arising from oil transactions. The dollar drain on oil account is larger than for any other item. For the year 1950 it had been estimated on the basis of current prices that the net dollar outgoing would amount to $625 million, of which $350 million would have arisen from the operations of American Oil companies in the U.K. and the rest of the sterling area, and $275 million from the world-wide operations of British oil companies. The former relates to the oil which American oil companies sell in the sterling area, currently about 13 million tons a year. The latter, which has already been substantially reduced, is the dollar element in the cost of producing and distributing about 80 million tons of oil, of which more than half is marketed outside the sterling area for much needed foreign currency.

As a result of increased production and the maintenance of restrictions on consumption, British oil companies expect to have available in 1950 some surplus oil over and above what they will need to supply their established markets.

In view of the dollar deficit of the sterling area, H.M. Government feel obliged to adopt a policy of requiring oil importers to absorb the above-mentioned surpluses before drawing supplies from dollar sources. By this means, we expect to achieve a saving of 5 to 10 per cent of the above net dollar outgoings on oil in 1950.

H.M. Government are, however, prepared to consider any proposals which may be put forward in order to minimize any immediate practical difficulty to the U.S. oil companies which the implementation of this policy may create and have initiated discussions to that end with the companies concerned.

The manner in which in the longer term the above-mentioned surpluses can best be utilized without undue hardship to the foreign investments and operations of American companies is one of the subjects under discussion in the current U.S/U.K. oil talks. The measures under discussion to reduce the dollar drain on oil account include adjustments in operating costs and procedures of the various companies to minimize dollar outlay.

In view of the above it will be clear that there is still a considerable dollar element in oil and the importance of economy in its use remains unaltered.

# PERSONAL NOTES

*R. W. Knight*

**R. W. Knight,** who has been managing director of Price's Patent Candle Co. Ltd. and Price's Lubricants Ltd. for over thirteen years, retired on December 31. His service with the parent company dates back to August 15, 1899, when as a boy of 14 he entered the Battersea office. By 1917 he had risen to the position of head of the Export Order Department, going to the city office in 1922 as a senior member of the overseas selling staff. Four years later he was made chief of that Department, returning to Belmont in the capacity of assistant commercial manager in 1927. He was appointed commercial manager on January 1, 1932, and was elected to the Board of Directors early in 1935.

He is succeeded by **E. J. A. Guest** who has been assistant general manager for the past four years.

*E. J. A. Guest*

**E. Peter Wright,** Stud.Inst.Pet., has been awarded the degree of Ph.D. at Birmingham University (Department of Chemical Engineering), his thesis being on "The use of chemical additives in improving the cetane numbers of diesel fuels."

**V. S. Butler,** Under-Secretary, Ministry of Fuel and Power, received the C.M.G. in H.M. the King's New Year Honours List.

**H. S. Gibson,** C.B.E., F.Inst.Pet. (*Member of Council*), has been appointed managing director of Iraq Petroleum Co. Ltd., and associated companies. In 1922 he joined the Anglo-Persian (now Anglo-Iranian) Oil Co. Ltd. as production engineer, was made production manager in 1930, and in 1945 was made general fields manager. He returned to England in 1949 and took charge of the company's Research Station at Kirklington Hall, Nottinghamshire. He was awarded the Redwood Medal of the Institute in 1947 for his work on the control of limestone reservoirs.

**John Skliros,** O.B.E., retired from the board of Iraq Petroleum Co. Ltd. on December 31 after twenty-five years association with the company and fifteen years as managing director. From 1914 to 1923 he held various political appointments in the Middle East and in the latter year became associated with the Anglo-Persian Oil Co. Ltd. in connexion with a projected refinery to supply oil to Iraq. In January 1930 he became acting general manager to the Iraq Petroleum Co. Ltd., in October 1931 general manager, and in July 1934 managing director.

**A. T. Wilford,** F.Inst.Pet. (*Member of Council*), has recently been awarded the Crompton-Lancaster Medal of the Institution of Mechanical Engineers for his paper on "Lubrication of engines in public service vehicles." He has also been elected a Fellow of the Royal Institute of Chemistry.

**Dr M. Souders,** head of the chemical engineering research section of the Shell Development Co., Emeryville, California, has been declared 1949 winner of the Celanese Corpn of America Professional Progress Award in Chemical Engineering. In his acceptance address before the American Institute of Chemical Engineers, Dr Souders said that at home and abroad "anxiety is the vinegar in every dish and the lumps in every bed." But to the engineer, he

added, the outlook is by no means hopeless; in fact the conditions of the problem are vaguely familiar to every process engineer, and seem to require the methods and discipline of engineering.

**Dr George Granger Brown,** head of the Department of Chemical Engineering at the University of Michigan, has been appointed director of engineering for the Atomic Energy Commission.

**George H. Freyermuth,** manager of Public Relations Dept. of Standard Oil Co. (New Jersey), has been elected chairman of the Oil Industry Information Committee in America. The main objective of the Committee's 1950 programme is to show the American public how oil contributes to their well-being.

**Col. L. C. Hill,** D.S.O., M.C., has been elected President of the Institution of Mining and Metallurgy for the session 1950-51.

**A. W. Lawson,** C.B.E., a director of Shell-Mex and B.P. Ltd., has recently retired after forty-four years' association with the company and its predecessors. Throughout he has been closely associated with bulk distribution methods. During the war he was chief operating officer of the Petroleum Board and for his services was awarded the O.B.E. in 1943 and the C.B.E. in 1948. For his work in connexion with underground storage and pipelines, the U.S. Government awarded him the Medal of Freedom with Bronze Palm. He became a deputy general manager of the company in 1944 and a director in 1945.

**C. G. Kirkbride,** vice-president in charge of research and development, Houdry Process Corpn, has been elected a director for 1950 of the American Institute of Chemical Engineers.

**F. A. C. Guépin** has been appointed a director and managing director of the Anglo-Saxon Petroleum Co. Ltd. and of the Shell Petroleum Co. Ltd., and also a member and delegate member of the Board of the Bataafsche Petroleum Mij.

**J. W. Platt,** a member of the Board of the Bataafsche Petroleum Mij has been appointed a delegate member of the Board.

It is with regret that we record the death, on January 1, of **Percy Cowderoy,** who was for a number of years a Member of the Institute. He first entered the petroleum industry in 1909 as a driller with the Natrona County Oil Syndicate, Wyoming, a position which he held until 1914. During this period it is believed that he erected the first all-steel derrick used in the U.S.A. Later he became a field manager in Trinidad and in France, and for many years prior to his death was chief engineer to Barclay Perkins & Co. Ltd.

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## CBMPE OVERSEAS ADVISORY SERVICE

The Council of British Manufacturers of Petroleum Equipment has recently set up an Overseas Advisory Committee, its terms of reference being: (1) To keep up to date the Council's knowledge of the various areas; (2) To advise members planning to go overseas; and (3) To advise members on questions of overseas representation or tours.

A series of panels have been formed which will prepare booklets designed to give information helpful to anyone visiting its companies overseas. Booklets covering the Middle East, the Caribbean, and North America are in course of preparation and others are contemplated.

Arrangements are also being made whereby visitors to Britain from overseas can be put in touch with those likely to be of assistance to them.

The Council has also issued a booklet describing its aims and objects, and its organization.

# PETROLEUM IN PARLIAMENT

*Middle East Oil*

The Secretary of State for Foreign Affairs was asked (December 5) what steps H.M. Government had taken or would take to assist Petroleum Concessions Ltd., Petroleum Development (Oman and Dhofar) Ltd., and Petroleum Development (Trucial Coast) Ltd., at present exploring for oil round the Arabian coast between Qatar and Aden. The reply was that the companies have been afforded all proper assistance by local representatives of H.M. Government.

*Dollar Oil*

Among questions put to the Paymaster-General in the House of Lords by Earl Howe on December 13, were the following: (1) How much is spent in dollars per annum on petrol of less than 80 octane value? (2) What is the amount of royalties paid in dollars for petrol produced in the sterling area? (3) What is the amount paid by American interests for the purchase of petrol produced in the sterling area? (4) How much petrol is now produced in this country per annum, and what is the extent of the increase in these amounts which can be expected for 1950 and 1951? (5) What is the value for 1948 and 1949 respectively of equipment for the production of petrol made in this country and exported?

In the course of his reply, the Paymaster-General said: (1) In the twelve months ended June 30, 1949, the U.K. imported from dollar sources petrol of less than 80 octane to the value of $53 million at f.o.b. prices: this excludes the dollar element in the costs of oil from what are called sterling sources. (2) Royalties are paid on crude oil, and not on petrol, and no dollar royalties are paid on crude oil obtained in the sterling area. Most of the so-called sterling oil is not, however, produced in the sterling area but in other countries, such as Venezuela and Persia. Royalty payments to such countries at present involve, directly or indirectly, a substantial dollar expenditure. (3) Dollars paid for petrol produced in the sterling area or by British-controlled companies throughout the world are not recorded separately, but our estimate of the f.o.b. value of petrol sold by these companies to United States interests in 1948-49 is 13,000,000 dollars. (4) The total production of petrol in the U.K. during the year 1948-49 was 1,128,000 tons. It is anticipated that production will have increased to 1,680,000 in 1950 and 2,220,000 tons in 1951. (5) Equipment for the production of petrol is not separately distinguished in the trade accounts, and figures of exports are therefore not available. From figures released by the Oil Companies Materials Secretariat, it appears that the total value of export orders placed in the United Kingdom by the oil companies for materials and equipment for all purposes connected with the production, refining, and distribution of all grades of oil has been as follows: for delivery in first half of 1948, £28,700,000; for delivery in second half of 1948, £32,400,000; for delivery in first half of 1949, £35,100,000.

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## "WORLD TRADE DIGEST"

The aim of this new publication, which first appeared in November 1949, is to provide abstracts of industrial information taken from the principal British and foreign publications. The scope is wide, the contents of the first number ranging from zipp fasteners to the Metal Exchange, from the Channel tunnel to air freight, from the oil industry to Scottish wool. Of pocket size (5 in × 7¼ in) price is 1*s* per copy or 15*s* per year post free from Eastern World Ltd., 45 Dorset Street, London, W.1.

# REVAMPING OF REFINERY PLANT

By W. R. PRENTICE (Assoc. Fellow) and G. W. LOYND (Assoc. Fellow)

PETROLEUM technology and the application of petroleum products have formed the vanguard of the industrial development which has been the outstanding feature of the present century. The search for new and improved products to meet the demands of industry and commerce continues apace. The already rapid advance occasioned by the mechanization of our civilization was even further stimulated by the war. But the incentives of war have not given way to a lethargy of peace: on the contrary the post-war world expects from the petroleum industry an increase in the volume and quality of its products. The industry itself has endorsed its ability to meet and has often anticipated these demands, and it has achieved these remarkable feats of production despite the manifold difficulties by which it has been confronted.

This development has been world-wide, but has been thrown into particular prominence in this country by the need to reduce dollar expenditure and stabilize our economy by an accelerated export programme. The position has been embarrassed by the prevailing shortage of materials and labour and the attendant uncertain delivery dates of new equipment. Much new plant has been completed and is still in the course of construction—plant to manufacture new products and to process new feedstocks. But at the same time a great deal has been accomplished with existing equipment. Plant has been modified or enlarged to increase capacity or to improve product quality. The wartime demand for certain products has diminished or disappeared entirely and the redundant units have been taken into service for the production of different products, sometimes with only slight modification, sometimes for entirely new processes which have entailed large-scale alteration and addition. It is this modification to plant design, whether to a greater or lesser degree, that will be considered under the term "revamping".

In an article of general interest no attempt can be made to present an exhaustive treatise on the technical details of revamping. The reasons for instigating a revamp are numerous and may vary from overcoming a minor process problem to complete conversion of a plant to a different purpose. Consequently the method of carrying out a revamp varies considerably, depending on the desired result. However, certain principles are universal to all. While from the operating viewpoint a plant is regarded as a single unit, from the technological angle it is composed of a number of items of equipment arranged and connected in a certain order. Much of this equipment such as pumps, heat exchangers, columns and furnaces is common to many different types of plant. A revamp entails modifying, enlarging or replacing some of these pieces of equipment or rearranging them.

In every instance the first step is to decide quite clearly what result is desired. Secondly, a close study is made of existing plant conditions and all relevant data are collected. From this, the general approach to the problem is mapped out. Thirdly, the detailed alterations are calculated and their practicability checked, experimentally where possible, and the effect of the change on the other parts of the plant and the refinery is considered. Fourthly, estimates are prepared of the cost of alteration and of subsequent operation, from which the pay-back time is calculated. The delivery time of any new equipment required and the availability of labour for carrying out

the work must also be taken into account. From this complete survey a decision can be taken on the feasibility of the revamp, and, if favourable, the work is put in hand with the minimum dislocation to normal plant operation.

This then is the general procedure. In order to study in more detail the scope and technique it is proposed to consider some of the reasons for undertaking a revamp, and to discuss under these headings the general methods employed. It should be stressed that every case must be considered on its own merit and, within the general framework of the procedure outlined above, unorthodox approach is common.

### Overcoming Process Problems

From time to time in the life of every plant new factors emerge which make difficult or impossible the production of satisfactory products at the normal capacity of the plant. The cause is generally self-evident—some change in feedstock composition or product specification is a typical example. Many of these problems can be solved by changes in operating technique but on occasion a structural change proves necessary. Every refiner is familiar with the diversity and frequency of this type of problem, and provides the solution by an equal variety of methods. In every case the general procedure already outlined is applicable.

### Increase of Production

In most refinery plant the capacities of the various pieces of equipment are not exactly in balance. It is, therefore, often possible to increase the capacity of the bottle-neck and thus increase the capacity of the plant as a whole. Production may be increased by increasing either the on-stream time or the throughput. Each of these methods will be considered.

#### *On-stream Time*

A study of the operating records over, say, the previous twelve months will reveal the number of days on stream and days shut down. The shutdown records are then analysed, particular attention being paid to the number, frequency, duration and cause of shutdowns. It may be found that a frequent cause is the failure of one or two particular items of equipment. If the cause is mechanical failure an improved design should be sought; if due to corrosion some alternative corrosion-resistant material should be taken into service.

Another common reason for frequent shutdowns is the necessity for periodic cleaning of parts of the plant. The source and cause of the accumulation should be found. It may be possible to reduce or eliminate this by a change in operating technique or by revamping. In some cases spare equipment can be installed to duplicate existing equipment and thereby permit cleaning to be done without shutting down the plant.

Apart from reducing the frequency of shutdowns, steps must also be taken to reduce the duration. This can be done to some extent by careful planning. Revamping some of the equipment to permit of easier access and more rapid working also helps.

#### *Throughput*

The method here depends on whether the process is batch or continuous.

(*i*) *Batch Process.*—The first step is to consider how the size of the batch may be increased. Where the limiting factor is the size of a container or reaction vessel it may be difficult to enlarge this. When, however, it is the operating capacity of some piece of equipment, it may be possible to revamp the equipment and thus increase its capacity. The next step is to prepare a time cycle of the process, i.e. the time taken for each step in the operating cycle. Each step in turn is then studied to see where the process can be speeded up. This may be done in some cases by

combining several steps. Another method of increasing the throughput is to convert the process to a continuous basis. Our knowledge of the reactions involved in processes is much greater than when many existing plants were built and with modern control instruments it is now possible to run continuously many operations which were formerly only possible on a batch scale.

(*ii*) *Continuous Process.*—The first step is to find which piece of equipment is the bottleneck. Conditions at the bottleneck are then analysed to find which feature of the equipment is limiting the capacity and what must be done to increase it. It may be possible to relieve part of the load by alterations to other parts of the plant, or to replace the equipment by a larger unit or to add an auxiliary.

### Reduction of Costs

Modern instrument and control mechanisms have now reached a high standard of reliability. By instrumentation of an old plant it is often possible to reduce operating manpower. The study of process mechanics has also improved considerably and many processes which were originally run on a batch scale are now operable continuously, for which the costs are generally lower.

The first step is to secure an accurate statement of the existing manufacturing costs. These are usually given under the following headings:

*Chemicals*
*Operation*
*Maintenance*
*Supervision*
*Utilities*
*Laboratory Testing*

These items will be considered in turn.

*Chemicals*

Chemicals used in petroleum refining may be divided roughly into two groups:

(*a*) *Circulation Chemicals.*—These are chemicals which are recovered or regenerated after use and returned to the system. Under this heading come the various solvents and the specially licensed gasoline-treating solutions. Costs may be reduced in this case by using a cheaper grade or substitute or by reducing losses. Losses may be either mechanical by leakage, spillage, or evaporation, or chemical by decomposition. Mechanical loss may be reduced by improved design and careful operation. Decomposition may be reduced by revamping the plant to permit operation at lower temperatures, to reduce the amount of air in contact with the chemical, or by removing from the system any metals which catalyze the decomposition. Where there are substances present in the feedstock which accelerate the decomposition, it may be advantageous to install facilities for pre-treating the feed.

(*b*) *Consumed Chemicals.*—Into this category come chemicals which cannot economically be recovered, the principal ones being sulphuric acid, caustic soda, and fuller's earth. In some cases consumption may be reduced by revamping the plant to improve the reaction kinetics by effecting more vigorous and efficient mixing or by carrying out the process at a more suitable temperature.

*Operation*

This is normally split into labour and materials.

(*a*) *Labour.*—On many plants it is often possible to reduce the work to be done by the operating crew, but it is uneconomical to reduce the work unless the time saved can be usefully employed. Instrumentation is a method of reducing operating labour which receives almost universal acceptance nowadays, and the use of the conventional controllers of temperature, pressure, flow and liquid level is so widespread that little need be said about them. There are, however, advantages arising from good

instrumentation other than saving of labour, among which might be mentioned the fact that modern control instruments do the job better than an operator and the resultant steady operation makes for higher yields, lower utilities consumption, lower maintenance costs and longer on-stream time. Labour can also be saved by improving the arrangement of the equipment. In older plants, pumps and instruments are often somewhat scattered. By regrouping this equipment to form a central control room, it is sometimes possible for one man to do what formerly took two or three men. Yet another method of reducing labour costs is to revamp the refinery to allow the use of mechanical handling devices. Common refinery operations such as handling, stacking and loading barrels can be performed very efficiently by fork-lift trucks with great economy in man power and time.

(*b*) *Materials.*—This is normally a small item in costs and consists mainly of cleaning material and protective clothing. Some economy can be effected by the revamping of old equipment so that less cleaning is required and protective clothing rendered unnecessary.

*Maintenance*

This also is normally split into labour and materials.

(*a*) *Labour.*—The question of reducing the frequency of shutdowns has already been discussed. By careful inspection and scheduling of shutdowns it is possible more nearly to approach the ideal of a constant amount of work for the maintenance crew. This ideal is of course unattainable in practice since even in the best refineries unexpected shutdowns occur but the effort to attain this should never be relaxed. To reduce the downtime of the plant, as many men as can usefully be employed should be put on the job, but a balance must be struck between short downtime and an excessively large maintenance crew. Several of the methods by which maintenance time may be economized have already been mentioned.

(*b*) *Materials.*—Reduction of material costs is often a rather delicate problem. Equipment which has to be renewed frequently may be replaced by articles made of more durable materials or of improved design, but a careful economic study must be made to decide whether it is cheaper to renew frequently or to employ more expensive materials.

*Supervision*

At first it might appear that revamping has little bearing on supervision. However, it should be borne in mind that the smoother the operation of the plants, the less supervision is required.

*Utilities*

Under this heading are grouped fuel, steam, air, cooling water and electricity.

(*a*) *Fuel.*—Reduction in fuel costs is largely a matter of reducing fuel consumption. This may be effected by revamping the plant to run at lower temperatures and by greater use of heat exchange. This subject is well covered in the literature published by the Ministry of Fuel and Power.

(*b*) *Steam.*—The efficient use of steam embraces a very wide field and it is often possible to effect an appreciable reduction in overall consumption by making a careful survey of existing conditions and revamping the system accordingly.

The subject is very adequately treated in the "Efficient Use of Steam" by Oliver Lyle,* and it will only be mentioned here that the utilization of exhaust steam and the recovery of condensate are two important facets of the subject which very often repay a critical study.

* H.M. Stationery Office.

(*c*) *Air.*—Air costs may be reduced by decreasing either the air consumption or the generating pressure. Much of the air used on a refinery is for mixing or agitation and it may be possible to effect some reduction in consumption by improving the design and layout of equipment. Some economy may also be possible through revamping the supply system. Where there are a number of compressors scattered throughout the refinery, by tying them into a common main it may be possible to reduce the number of compressors operating. On the other hand, where there is a main supplying an intermittent consumer over some distance, it may be more economical to isolate this branch and install a small compressor on the site for use when required.

(*d*) *Cooling Water.*—This is largely a matter of reducing consumption and reducing maintenance costs on the system. In many plants there is no control over the flow to coolers and condensers and, indeed, often no means of measuring inlet and outlet water temperatures. The installation of automatic control or at least temperature indicators and manual control valves will effect a considerable reduction in consumption in many cases. The main factors affecting maintenance of cooling water systems are scale deposition, corrosion, and organic growth. These have the effect of reducing heat transfer coefficients, shortening life of equipment, and increasing power consumption on account of the pressure drop. Treatment of the water to eliminate or reduce these factors and replacement of corroded equipment with more resistant materials will bring about a decrease in maintenance and possibly also in consumption.

(*e*) *Electricity.*—Electricity is used on refineries for light, power and heat. Modern lighting equipment is much more efficient than the older type and in many cases the replacement of old fittings by new equipment shows a good pay-back time. The use of electricity for power and heat is very closely tied up with the use of steam. Consequently there is no standard method of dealing with the subject and each case must be considered in the light of local conditions and prices.

*Laboratory Testing*

There are now on the market, plant instruments for the measurement of such physical properties as specific gravity, viscosity and acidity, the accuracy of which is beginning to approach that of routine laboratory testing. The installation of these where applicable reduces the cost of sampling and testing besides giving the operating crew more rapid results. Also the general revamping of a plant to promote steadier operation enables the frequency of sampling and testing to be reduced.

## Utilization of Plant for Different Purpose

Market demands are continually varying and on many refineries there may be found a plant which is no longer in use. The equipment of which this is composed can often be used for the manufacture of some other product.

The first step is to prepare a flowscheme and heat and material balance of the new process. From this the main dimensions and capacities of the various items of equipment are calculated. A list is then prepared of the equipment on the existing plant under the headings of dimensions, capacity, materials of construction and special features. A similar list is made of all equipment which can be made available from other plants or from stores. The existing plant equipment is then fitted into the most likely positions in the flowscheme, any remaining positions being filled as far as possible from the other equipment available. The capacities of the equipment are now calculated in their new duties and, if necessary, the positions are adjusted to give the best arrange-

ment. Attention is then given to the possibility of fabricating any of the outstanding items from surplus equipment or materials.

The next step to be considered is instrumentation. From the flowscheme the instrumentation is planned and a list of instruments prepared. This is compared with the instruments available from the existing plant and other sources and the possibility is examined of fabricating any of the outstanding instruments from materials available.

So far only the plant itself has been considered. The question of utilities must now be examined. The future consumption of the various utilities must be estimated and compared with the capacity of the existing supply system to see if any alteration need be made to the system. If any increase must be made to the supply, the system must be checked back to the source to ensure that the increased capacity can be borne at all parts of the system.

Separate layouts of the plant are then made from the point of view of operation, maintenance, safety and economy of construction. (It must be borne in mind that any change of position of heavy equipment may necessitate new piling.) The four layouts are then compared and a compromise reached.

From this layout the quantities of pipe and fittings are computed. The usable pipe and fittings on the plant are ascertained, together with that available from other plants and material stocks. Any changes to be made in the steam, air, water or fuel supply must also be taken into account in calculating both the new piping required and the old piping available.

At this stage a final check is made over the whole design to see if there are any points where the requirement of new equipment or materials can be reduced. Finally the new equipment is designed, lists of materials compiled, cost estimates prepared, and the whole project passed over to the construction department.

### Removal of Superfluous Equipment

In many plants there is equipment which is not essential for the operation of the plant and which may be removed. Apart from the general desire for tidyness, there may be good arguments in favour of its removal. It may be a source of heat loss or a charge on maintenance; its removal may facilitate operation or maintenance, or the space may be wanted for other equipment. A particularly good reason at present is that it may be of use on another plant.

### An Example of Revamping

This article has dealt only with the general aims and technique of revamping. It is felt that it would not be complete without at least one specific example of what has been achieved by a vigorous approach to an actual problem. The most striking illustrations of course are given by those plants which have been converted from one service to another. Both in Britain and particularly in America a large number of aviation gasoline plants were constructed to meet wartime requirements. One such unit was the United States government-owned 100 octane gasoline plant near Duncan, Oklahoma. This was shut down at the end of hostilities and doubt existed that it could ever be operated profitably under peacetime conditions. That doubt has been dispelled and to-day this refinery, purchased by a private operator, is processing 3000 tons/day of Oklahoma crude into a variety of products.

The principal elements of the wartime plant were a two-stage fluid catalytic cracking plant with a charging capacity of 2000 tons of fresh feed per day, a gas concentration system, a 400 ton/day hydrogen fluoride alkylation unit, a 50 ton/day isomerization plant and a modern boiler plant. Auxiliary equipment included three large forced-draft cooling towers necessitated by the heavy water requirements of the alky-

lation plant. A plentiful source of water supply was assured by a pipeline system, including pumping facilities, to Lake Duncan, about 8 miles away. Tankage included rundown, charging stock and product tanks among which were three 7000-ton floating-roof gasoline tanks and a number of spheres for the storage of butane, *iso*butane and butylenes.

The purchase was consummated in October 1947, and the project got under way at once. The problem was to transform the refinery to profitable commercial operation, making use of the existing facilities to the fullest extent.

The refinery possessed no pipelines to afford cheap transportation of crude in and products out, inasmuch as it had been designed to operate exclusively on gas oil which was delivered by road wagon from eight nearby refineries, and to produce aviation gasoline which was shipped out by tank car. Pipelines were a necessary part of the reconversion project.

The company's original refinery is located about 100 miles north-east of Duncan. While the reconstruction work was in progress, an 8-in products pipeline was laid between the two refineries for products exchange and to storage at the old refinery. At the same time a short line was laid to bring crude from the Velma field to the refinery.

Needed for the new programme was a topping unit and desalting equipment, a necessity for treating Velma crude, which is high in salt, sulphur and asphalt content. Furthermore a vacuum unit was needed to recover the heavy, waxy gas oil from the topped crude, and a viscosity-breaking operation was required to make a marketable fuel oil from the heavy residue. There was no provision for treating the products of crude distillation.

As operated in wartime, the light gases from the catalytic cracker were charged to the alkylation unit to produce aviation alkylate. That procedure being considered no longer advantageous under the new operating schedule it was desirable to install a polymerization unit and a propane separation unit to prepare this product for the market.

The original catalytic cracker was built for two-stage operation, one stage for cracking fresh gas oil and the other for retreating the cracked gasoline. The two stages had a common regenerator but two reactors, two large fractionating columns and separate auxiliaries such as condenser boxes. It was proposed to operate the catalytic cracker as a single-stage unit, which required extensive stages in both the reactor and regenerator sections. The large feed heater was not necessary for this operation so this heater and the retreatment fractionating column were taken as the basic elements for a new topping unit.

In order to increase the crude capacity of the new plant it was decided to preflash the crude. To accomplish this a heat exchanger from the alkylation unit and the debutanizing tower from the gas concentration system were combined into a preflashing plant. By this scheme about 15 per cent of light straightrun gasoline is flashed off when the charge to the crude unit is preheated to about 400 F. The improvised crude unit and preflashing system give the plant its 3000 tons/day crude capacity.

A large settler from the alkylation unit was converted into a vacuum unit, with the addition of a small heater and necessary auxiliaries.

A polymerization unit was built to handle the gases from the crude unit and the catalytic cracker. A propane unit was also installed. These were constructed by the utilization of equipment on the ground, with the exception of the polymerization unit reactors and the propane storage tanks which were bought new. Treating equipment for the various products was likewise built.

Actual construction work began in

October 1947 and proceeded on a carefully worked out schedule. On December 5 the desalter and crude unit went into operation. In the meantime, construction of additional storage had been going ahead so that sufficient tanks were completed to store the products which were to be further processed when the necessary elements of the plant became ready.

Construction of the vacuum unit had been so timed as to have it ready for operation before the accumulated stocks of topped crude from the operation of the crude unit became too great. All the light products from the crude unit were immediately made saleable, the necessary treating units having been provided in advance.

Using one of the existing towers, the straightrun gasoline was stabilized to remove propane and lighter fractions, including hydrogen sulphide. The vacuum unit flashed off gas oil as charge for the catalytic cracker, leaving heavy asphaltic bottoms of high viscosity.

In order to render this rapidly accumulating material marketable and dispose of it before the storage tanks were filled, the next two moves were to get the viscosity-breaker into operation to reduce the viscosity of the vacuum bottoms, and to start up the catalytic cracker which would produce low viscosity material for blending.

While work on the catalytic cracker was proceeding the gas concentration system was being re-modelled to separate the large quantities of propane, propylene, butane and butylenes which the catalytic cracker would produce, and the polymerization unit was being constructed to convert these fractions into polymer gasoline. The timing was accurate. Both the gas concentration system and the polymerization plant were ready when the catalytic cracker went on stream.

Fractionating equipment was installed to separate butane from the polymerization unit's effluent gases, and this butane, stored in the spheres, is used for blending with gasoline to control vapour pressures.

Increasing its production step by step, the plant has been in full operation for more than a year now, demonstrating how a refinery designed for one specific purpose can be converted to an entirely different operation.

In the preceding pages an attempt has been made to explain the meaning of revamping, and to give some idea of the various general techniques employed. It is stressed that the method depends more on ingenuity and the application of fundamental chemical engineering principles rather than abundant resources of men, equipment and materials. As such it can be applied as successfully in a small refinery as in the large one. Without the constant application of new and improved methods of production stagnation in the industry and loss in potential would inevitably result. Revamping of refinery plant has therefore played and will continue to play an important role in maintaining the efficient service which petroleum has given to the world.

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## SPECIAL PRODUCTS COURSE

A course of six lectures on Special Products from Petroleum is being held at the Sir John Cass College, Jewry Street, London E.C.3., on Thursday evenings (6.30 p.m.) beginning on March 2. W. S. Ault, F.Inst.Pet., will take the chair at each lecture. Fee for the course is 15 -. Subjects are: *General introduction*—W. S. Ault (Mar. 2), *Corrosion preventive compounds*—W. Pohl, F.Inst.Pet. (Mar. 9), *Metal working lubricants*—W. H. Adams (Mar. 16), *Electrical oils*—V. Biske, F.Inst.Pet. (Mar. 23), *Technical white and medicinal oils*—G. H. Harries, F.Inst.Pet. (Mar. 30), *Petroleum waxes and petrolatums*—S. T. Minchin, F.Inst.Pet. (April 6).

## U.S. NATURAL GAS INDUSTRY IN 1948

Marketed production of natural gas in the U.S.A. in 1948 (5,148,020 million cu. ft.) was 12 per cent over the 1947 figure, while accountable waste was 810,178 million cu. ft., a decrease of 24 per cent. The Bureau of Mines, U.S. Dept. of the Interior, reports that consumption was 4,945,149 million cu. ft. Details extracted from the report (MMS. 1806) are:

| | 1948 | 1947 |
|---|---|---|
| | *Million cu. ft.* | |
| **Production** | | |
| From gas wells | 4,588,547 | 3,769,768 |
| From oil wells | 2,590,230 | 2,963,462 |
| Total | 7,178,777 | 6,733,230 |
| **Disposition:** | | |
| Marketed | 5,148,020 | 4,582,173 |
| Repressuring | 1,220,579 | 1,083,119 |
| Vented and wasted | 810,178 | 1,067,938 |
| Total | 7,178,777 | 6,733,230 |
| **Consumption:** | | |
| Domestic | 896,348 | 802,150 |
| Commercial | 323,054 | 285,213 |
| Field (drilling, pumping, etc.) | 1,021,513 | 933,761 |
| Petroleum refineries | 441,470 | 363,892 |
| Carbon black | 480,646 | 484,882 |
| Portland cement | 72,139 | 60,499 |
| Other industries, including public utility power plants | 1,709,979 | 1,496,147 |
| Total | 4,945,149 | 4,426,544 |

Domestic consumers numbered 13,508,000 and commercial consumers 1,145,000 in 1948, increases of 11 and 10 per cent respectively over 1947. Of the domestic consumers 2,798,410 used mixed natural and manufactured gases and 160,430 commercial consumers used such gases.

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**Hydrazine.**—Hydrazine hydrate (60 per cent) is now available in the U.K. at 8*s* 6*d* per lb in ton lots. The 90 per cent and 100 per cent hydrate is also available in research quantities. Enquiries should be addressed to British Chemicals and Biologicals Ltd., 43 Regent Street, Loughborough.

## NEW SHIPS' RUDDER DESIGN

A significant development in the design of ships' rudders, which has been evolved by H. A. Wilson, of Esso Transportation Co. Ltd., has recently been tried out on the Anglo-American Oil Company's 18,000-ton twin-screw tanker, *D. L. Harper*.

The steering of twin screw ships in confined and shallow waterways, where slow speeds are necessary, has been a long standing problem. In some cases rudders have to be turned over as much as 20° to 25° before they enter the propeller race and before the rudders feel the reaction from the propellers.

A critical examination of all the circumstances led to the experiment of attaching two small auxiliary rudder blades to the main rudder in a winged-out fashion, so that, with the rudder admidships, the auxiliary blades were just within the propeller races. Subsequent trials in the *D. L. Harper*, thus experimentally fitted, showed that the degree of helm necessary to maintain the ship's course at reduced speeds of 8 and 6 knots even with a strong beam wind blowing was less than half that previously needed. During passages through the Suez Canal, the Master of the tanker reported that both when the ship was in ballast and when she was laden it was possible to hold the vessel on her course for most of the time with not more than 5° of helm. The steering qualities were described as being not only good but exceptional.

A patent application (28596 49) has been filed and further details are available from the Anglo-American Oil Co. Ltd.

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**Chromatography Equipment.**—Descriptive literature regarding apparatus for chromatographic analysis is available from Shandon Scientific Co., 2 Robert Street, Adelphi, London, W.C.2.

# TRENDS IN REFINERY PRACTICE*

*By* M. A. L. BANKS (Fellow)

*Introduction*

To understand a trend it is first necessary to appreciate the influences at work which bring about the trend. In the time available it is not possible to touch on all the aspects involved in the oil refining industry and certain important features will have to be omitted. Among these are lubricating oil production and the manufacture of aviation spirit, which are highly specialized problems each worthy of a complete discussion.

It is proposed to take the main refinery processes, topping, cracking, both thermal and catalytic, and apply to them some basic figures for yields and costs with the object of seeing what is involved in the gradual increase in refining complexity.

It will be understood that the figures are approximate only and the purpose in presenting them is to use them from the comparative angle only.

*General Appreciation*

Two important influences which have been at work over the post-war years are, firstly, the demand for oil products in the U.S.A which, until recently, threatened to force a scarcity in other consuming areas and, secondly, the economic and currency difficulties facing so many nations, particularly in Europe, which have caused the governments of these countries to favour refining in their own countries.

With growing U.S. consumption reducing the western hemisphere's exports of oil products, there has resulted a quickening of the rate of production in the Middle East areas. Middle East crudes are therefore increasingly in use as base stocks for refining in the European consuming areas.

Before the war the production and consumption of oil in the U.S.A. was the dominating feature in the market and set the whole trend of quantity available and quality to be supplied elsewhere. Table I shows the U.S. consumption of the principal petroleum products in 1938 and 1947, with corresponding figures for Europe.

It is interesting to note that in 1947 a difference of 1 per cent in the U.S.A. consumption corresponds to a quantity of nearly one million tons, which is approximately equivalent to 25 per cent of the gasoline imported into the United Kingdom. Nevertheless, in spite of the huge quantities available and consumed on the American side of the Atlantic, for the economic reasons already mentioned the European continent is tending to develop its own industry on the basis of Middle East crude. This development can affect the quality of the products available, since,

TABLE I

U.S. AND EUROPEAN OIL CONSUMPTION IN MILLION TONS
(*percentages in brackets*)

| | 1938 | | 1947 | |
|---|---|---|---|---|
| | *U.S.A.* | *Europe* | *U.S.A.* | *Europe* |
| Gasolines | 61 (48) | 13 (45) | 90 (41) | 11 (28) |
| Middle distillates | 23 (18) | 7 (24) | 53 (24) | 11 (28) |
| Fuel oils | 43 (34) | 9 (31) | 77 (35) | 17 (44) |
| Total | 127 | 29 | 220 | 39 |

*An address to the S. Wales Branch of the Institute of Petroleum on April 1, 1949.

as will be shown later, considerable material and manpower effort has to be expended to manufacture high quality products and those countries which have little raw material such as steel and coal may find it beyond their capacity to have products, particularly gasolines, which come up to the standard prevalent in the United States.

*The Refining Pattern*

Europe, therefore, is establishing a number of refineries based on Middle East material. These refineries when built will put Europe into much the same position as the United States, i.e., it will be supplied from a number of refineries mainly around one to two million tons per annum capacity. While the U.S. refineries work on a variety of crudes, the European refineries will tend to work mainly on Middle East crudes. The refining problems throughout the various European countries will, therefore, be all rather similar and somewhat different from those problems encountered before the war in countries where refineries were already established, e.g., France and Germany, which operated in certain cases on East Texas or similar crudes.

There will be a great opportunity for refinery people to get together and discuss and compare the results of their work. Such items as design, layout, time efficiency, corrosion prevention, treating problems, and the like will be very much to the fore.

The refining pattern employed will vary dependent on the policy of the particular government or the demands of the market (whichever dominates) of the country concerned.

First of the various steps involved in building up a flexible refinery is what came to be known in Great Britain as the Kettle development. The only main process employed is the distillation process, consisting of a unit with one main fractionating column with a pre-flash tower. Ancillary treating plant is of the simplest type. Operating on Middle East crude oil the gasoline produced would have a 50 octane number clear, kerosine would have to be acid-treated to produce a relatively satisfactory product, the gas oil would be of excellent quality with a high cetane value, while the dominating characteristics of the fuel oil would be the pour point and the sulphur content.

The yields of a representative Middle East crude oil using the distillation process only are shown as Case 1 in Table II.

TABLE II

YIELDS FROM A REPRESENTATIVE MIDDLE EAST CRUDE

| *Case* / *Process* | 1 *Distillation* | 2 *Distillation, thermal reforming* | 3 *Distillation, hydroforming* | 4 *Case 2 plus thermal cracking* | 5 *Case 2 plus catalytic cracking* | 6 *Case 3 plus catalytic cracking* |
|---|---|---|---|---|---|---|
| Gasoline | 23 | 26 | 27 | 29 | 37 | 38 |
| Kerosine gas oil | 20 | 14 | 15 | 35 | 25 | 26 |
| Fuel oil | 52 | 53 | 51 | 25 | 28 | 26 |
| Loss plus fuel consumed in refinery (fuel oil equivalent) | 5 | 7 | 7 | 11 | 10 | 10 |
| Octane number (C.F.R., M.M.) of gasoline with 1.5 cc T.E.L. | 65 | 70 | 75 | 75 | 75 | 79 |
| Steel installed*—tons | 11,000 | 13,000 | 14,000 | 16,000 | 18,500 | 19,500 |

*For 1 million ton refinery.

If improvement of the quality of the kerosine by extraction and other processes is ignored and a pumpable fuel

oil accepted as a product, the criticisms which can be directed against the yields shown for case 1 are mainly that the gasoline is low in both quality and quantity.

As far as effort to erect such an installation is concerned an approximate figure for the steel required would be approximately 11,000 tons for one million tons per year capacity, including 8,000 tons for tankage.

Secondly, assuming that more and better quality gasoline is required the next step is quite clear ; it is to install a thermal reforming unit.

In order to make the figures comparative it is necessary to make certain basic assumptions, and in this series it is assumed the reforming equipment would operate on material boiling between 100° and 200°C and that the fuel produced would have been blended for maximum middle distillation production consistent with the fuel oil being pumpable. On this basis we come to Case 2 in Table II.

Compared with Case 1 there has been an improvement in the yield and quality of the gasoline at the cost of the middle distillate yield and with some increase in fuel oil. The steel required has gone up to approximately 13,000 tons, of which tankage still accounts for 8,000 tons.

Thirdly, as the purse of the particular country concerned lengthens, more improvements in the quality and availability of distillates are required and for this step it is assumed that a 75 octane product will be required.

For the purpose of the discussion two methods are considered in comparison. One is the use of the hydroforming process, which, while considerably more expensive in material and hence total cost, does give an improved yield. The hydroforming process (Case 3) is therefore put in as an alternative to thermal reforming. The other route is the addition of the thermal cracking process (Case 4), in other words the deliberate step of altering the black to white ratio by processing the heavy residue type material for distillate production. The flexibility which the thermal cracking process provides is markedly brought out by the figures for the middle distillates, the five octane number increase from 70 to 75 has been achieved, and an increase in gasoline availability of 3 per cent in the case of the thermal cracking route. From the point of view of flexibility there is no question which is to be the more preferred.

In general from published information it would appear that most refiners throughout the world have avoided the adoption of the hydroforming process. The dominating factor in any decision between the two routes would be the question of the disposal of the fuel oil.

A point however must now be made which concerns the item "Loss plus fuel consumed in the refinery." This figure, namely the real loss in refining, has been raised from 5 in the case of distillation only, to 11 in the case of distillation plus thermal reforming plus thermal cracking.

From the angle of whether a refinery at the point of production or a refinery at the point of consumption is the more economical, the cost of the freight on the loss and fuel consumed must be debited against the latter plan. Thus, for a million-ton refinery the difference in fuel consumed between Case 1 and Case 4 is 6 per cent, or some 60,000 tons, equivalent to a freight charge of nearly £120,000 a year at £2 per ton.

Fourthly, there is the most flexible practical set-up known to-day. The catalytic cracking process can be applied in conjunction with catalytic polymerization, added to either thermal reforming, or to hydroforming. The results are shown in Cases 5 and 6 of Table II.

Of these two cases it is doubtful whether the hydroforming process would be installed in addition to the catalytic cracking process unless there were some very exceptional demand for

high octane gasoline. Case 5 may be said to represent the most highly flexible but practical set-up known to the refining industry.

The decision to install catalytic cracking instead of thermal cracking rests essentially on the importance of obtaining a high octane number gasoline. In order to obtain this high octane number and a greater gasoline yield there has been a reduction in the middle distillate production.

To provide such a flexible refinery requires nearly double the quantity of steel as the simple Kettle type. Thus, not only has the fuel lost and consumed been doubled, but the amount of equipment has been doubled and probably the number of people required to handle the process and ancillary equipment are in the same ratio.

ton, without allowing in the latter case for intermediate tankage. In the case of the clay treatment about ninepence would be for amortization, while the corresponding figure for acid and redistillation would be nearly 2*s*. Therefore, for a new installation acid treatment and redistillation are unlikely to be selected, a trend most acceptable by the refiner as it eliminates the need for the disposal of used acid.

There are several processes for the final sweetening of distillates, cracked or straight run, the costs of which are nearly equal. They are plumbite, copper chloride, bleach, and solutizer with plumbite finish, all of which on cost of equipment and cost of operation are very similar. The cost figures in Table III are to be regarded only as comparative.

TABLE III

TREATMENT PROCESSES—COMPARISON OF DIRECT OPERATING COSTS

| | *Plumbite* | *Copper Chloride* | *Bleach* | *Solutizer with Plumb Finish* | *Acid* | *Catalytic desulphurization* |
|---|---|---|---|---|---|---|
| | s d | s d | s d | s d | s d | s d |
| Operating . . . . | 1 1 | 1 7 | 2 0 | 11 | 5 3 | 3 8 |
| T.E.L. (for 70 O.N.) . | 9 10 | 9 10 | 7 11 | 7 11 | 8 4 | 4 11 |
| Amortization . . . | 6 | 8 | 7 | 8 | 7 | 2 4 |

*Treatments*

In the figures given of steel requirements allowance has been made for the treatment plants.

Changes made on the consumption side, during the war, which have continued into the post-war period, have had an important influence on the type of treatment to be employed in the refinery. The universal use of lead, with the necessity therefore for the petrol to be dyed, has made the conventional acid treating plus redistillation process almost obsolete for thermally reformed material. Based on a new installation to treat 5,000 barrels per stream day of pressure distillate, vapour phase clay treatment integral with a reformer would cost say 1*s* per ton, while acid treatment and redistillation would cost say 7*s* per

An interesting and dominating feature in this comparison is the cost of adding T.E.L., based on producing 70 O.N. straight-run spirit of 150° end point from Middle East crude. The high cost of acid treatment is brought out and the value of the improved lead response obtained by the solutizer is interesting. The figure shown for T.E.L. cost on the plumbite treatment is probably too low as this process, particularly in the case of straight run gasolines, depreciates the octane value, particularly when carried out under conditions short of perfect.

In considering the treatment process to be installed it is important to get the perspective correct. Thus, in a one million ton refinery, requiring say 11,000 tons of steel, the treatment plants

would require about 300 tons. From the capital viewpoint this is unimportant but since mal-operation of treating equipment can result in serious consumer complaints and loss of markets under competitive conditions it would seem that other things being equal a most important consideration for the selection of treatment plant is that it should be the type of process understood and preferred by the practical operator in the particular locality.

The question of treatment plant selection should not be left without reference to the process of catalytic desulphurization, in which the material is vaporized and passed at elevated temperature through a bed of catalyst. The particular advantage which this process shows is that it is not, as in the case of plumbite and copper chloride, merely a sweetening process where the sulphur is converted from a sour to a sweet form. The sulphur is actually removed. The result is a product with a high lead response, which can be of considerable importance when leaded octane values are at the 75 or 80 level. There is also an increase (up to 3 octane numbers) in octane number due to molecular rearrangement. Figures for catalytic desulphurization are given in Table III.

*Incidence of Operating Cost*

It is never satisfactory to compare the operating cost of a refinery in one locality with the operating cost of a refinery in another locality, since local considerations and requirements connected with such items as outside services, packaging, power supply, cooling water, etc., vary between localities. It is, however, worthwhile to look at the cost build-up for a specific operation.

The direct operating cost can be split into three groups: (*a*) Operating, including chemicals and labour; (*b*) Maintenance, including materials and labour; (*c*) Utilities, with which is bracketed fuel consumption.

TABLE IV

OPERATING COSTS PER TON INPUT

| | *Reforming* | |
|---|---|---|
| | 1938 | 1948 |
| | *s d* | *s d* |
| a. Operating . . . | 0 6 | 2 0 |
| b. Maintenance . . . | 1 5 | 7 5 |
| c. Services plus fuel . | 3 11 | 9 7 |
| Total . . . . . | 5 10 | 19 0 |

Table IV shows the direct operating cost for the years 1938 and 1948 for a reforming unit of approximately 4,000 b.s.d. capacity. The work which the unit did in the two years was approximately the same and it was shut down for practically the whole of the war.

What cost nearly 6*s* per ton in 1938 cost 19*s* in 1948. The services plus fuel item, while obviously the largest of the three costs, is probably not subject to great economies. On the other hand the maintenance cost increased to nearly six times the 1938 and is probably the most important item in plant operation to-day. Adequate corrosion prevention methods, steady operating conditions, and close organization of maintenance can all play their part in keeping these figures down.

*Conclusions*

It is worthwhile to look back on some of the figures which have been discussed and see what they really mean.

Started with the simplest possible refinery to make 23 per cent of gasoline of 65 octane number, the amount of effort involved in the erection was doubled and gave a refinery which could make 38 per cent of gasoline at 79 octane. The middle distillates changed from 20 to 26 per cent and the fuel oil was halved.

In the figures for the 1947 consumption in U.S.A. and Europe (Table I), the figure for gasoline consumed in Europe is 28 per cent of total oil consumption and the figure for U.S.A. is 41 per cent. The close approximation

of these percentages to the production figure quoted for simple and complex refining is interesting.

As far as the U.K. is concerned with the necessity to develop an export trade in motor vehicles, coupled with the general desire of the population for easy transportation, development of refineries must be towards greater complexity, i.e., the Kettle outlook is behind us.

The competition of U.S.A.-produced motor cars operating on high octane gasoline must be met by the U.K. car manufacturers, and this in itself creates a demand for improved fuels.

The greater complexity will make higher demands of the refinery technical man. The cost of an octane number at the 80 level is very much more than at the 70 mark and therefore it becomes most important to avoid any reduction due to faulty treatment for example.

The necessity for tight control of operating conditions makes the role of the instrument engineer increasingly important and an adequate appreciation of control instruments and their scope must be included in the make-up of a modern refinery.

The demand on the petroleum industry for more products of improved quality has begun—the manufacture of chemicals must be included in this—so the conclusion may be reached that the main trend in refining practice which must occur is the raising of the level of technical skill and no improvement in this aspect is too small to be worthwhile.

The writer gratefully acknowledges the help received from his colleagues in the Anglo-Iranian Oil Company in the preparation of these notes.

★ ★ ★

**Link Trainer for W.J.A.C.**—Shell-Mex & B.P. Ltd. have presented the Women's Junior Air Corps with a Link Trainer, a machine which enables a pupil to receive considerable flying training without leaving the ground. The trainer is to be used by No. 6 Region and is housed in University Buildings, Edmund Street, Birmingham.

## "OIL AND PETROLEUM YEAR BOOK."

In referring to this book on p. 374 of the December, 1949, issue, it was stated that the index gave references to companies no longer in existence. We are informed by the publisher that these back references now only relate to companies which have become dormant although still in existence.

★ ★ ★

## ENGINEERS WANTED

**PETROLEUM ENGINEERS** required for Bahrein Petroleum Co. Ltd. (a) **Production,** with over five years experience in reservoir engineering research or in performance data for wells in the observation and use of depth pressures, etc.; (b) **Mud Engineering,** with over five years experience this type of work; (c) **General,** with over five years experience drilling and re-drilling and repair of producing wells; (d) with **Geological** qualifications additional to (c). Age limit 40. Free board, air conditioned quarters, and medical attention plus 10 per cent of salary for married employees during initial two years separation period. Low living costs, paid leaves. Write with full particulars age, experience, education, salary required to Box 3221, c/o Charles Barker & Sons Ltd., 31 Budge Row, London, E.C.4.

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**MONSANTO CHEMICALS LIMITED** require a **Senior Executive** for work on Lubricating Oil Additives. The duties are those appropriate to a Sales Manager, and will include a large measure of responsibility for co-ordination of sales, production, research development, etc., and may involve travel in Europe and U.S.A. Future prospects are excellent and the post is designed to appeal to a Petroleum Specialist with wide experience in lubricating oils and a University background. Such a man would probably be not less than 32 years of age and would be offered an attractive salary commensurate with his specialized experience. The post is permanent and pensionable. Apply in writing, giving age, education, training and experience to Chief Personnel Officer, Monsanto Chemicals Limited, 8 Waterloo Place, London, S.W.1.

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## DRUM HANDLING

Drums, so largely used not only in the petroleum industry but in many other industries for the carriage of liquids are awkward things to manipulate. They have a habit of travelling in the wrong direction or developing rough and jagged edges, and need to be handled in the proper way if accidents and injuries are to be avoided.

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This complete unit is available for sale at a cost of ten guineas, and enquiries should be addressed to the Shell Petroleum Co., Ltd., Publicity Dept., 10-12 St. Mary Axe, London, E.C.3.

★ ★ ★

## "BIRMINGHAM UNIVERSITY CHEMICAL ENGINEER"

Under this title the Birmingham University Chemical Engineering Society, which incorporates the Student Section of the Institute of Petroleum, has published the first copy (October, 1949) of a journal. This journal is intended to provide students and staff with news of the Chemical Engineering Departments' activities, undergraduates with technical articles of interest, and chemical engineering firms with specialized articles.

The first number admirably fills this bill. There is a description of the growth of the Department from its inception, an account of present research work in the Department, a history of the Society and an account of its Annual Dinner.

On the technical side there are articles on mass-spectrometry, precautions in using compressed gases, wood distillation, and electrostatic precipitation.

It is proposed to publish three times yearly and price is 2*s* per copy. Application for copies should be sent to the Chemical Engineering Society, Birmingham University, Edgbaston, Birmingham 15.

# MEMBERSHIP CLASSIFICATION

From a recent survey of the membership rolls it is apparent that there are many Members in the Associate Membership or Associate Fellowship classes who have attained the necessary qualifications to apply for transfer.

The qualifications required for Membership or Fellowship are set out in By-Laws 8 and 9 as follows :—

**By-Law 8—MEMBERS**

A Member shall be not less than 30 years of age and shall satisfy the Council that he is a fit and proper person to belong to the Institute and that he has the requisite position and attainments, including at least five years in a position of superior responsibility in the petroleum or allied industries.

**By-Law 9—FELLOWS**

A Fellow shall be not less than 30 years of age and shall satisfy the Council that he is a fit and proper person to belong to the Institute; that he has suitable scientific and technological attainments, and that he has held for at least five years a position of superior responsibility in the domain of the science or technology of petroleum.

Membership and Fellowship are of equal status and Candidates are classified in accordance with their occupation.

Council are anxious that the classifications in the Institute should be as accurate as possible, and Associate Members and Associate Fellows with suitable qualifications are invited to apply for transfer to the higher classes.

## FORTHCOMING MEETINGS

### INSTITUTE MEETINGS

**The Importance of the Preservation and Packing of Equipment for the Oil Industry.** D. A. Williams. At 26 Portland Place, London, W.1, 5.30 p.m. (*tea* 5 *p.m.*), March 8.

**Testing of Temporary Protectives for Metals.** A symposium by members of the Temporary Protectives Panel. At 26 Portland Place, London, W.1, 2.30 p.m., March 29.

**Cold Starting Performance of High Speed Diesel Engines and their Fuels.** L. D. Derry and E. B. Evans. At 26 Portland Place, London, W.1, 5.30 p.m. (*tea* 5 *p.m.*), April 12.

*LONDON BRANCH*

**Distribution and Marketing in the U.K.** C. M. Merrick. At 26 Portland Place, London, W.1, 6 p.m. (*tea* 5.30 *p.m.*), February 22.

**Refining and Processing.**—R. B. Southall. At 26 Portland Place, London, W.1, 6 p.m. (*tea* 5.30 *p.m.*), March 30.

*NORTHERN BRANCH*

**The Petroleum Industry as a Career.**—A symposium by J. Dugdale Bradley, Prof. F. Morton, and Miss C. F. M. McIntosh. At Engineers' Club, Albert Square, Manchester, 6.30 p.m., February 21.

**Petroleum in Agriculture.**—F. Ellis. At Engineers' Club, Albert Square, Manchester, 6.30 p.m., March 21.

*SCOTTISH BRANCH*

**Nuclear Fission.**—Sir Wallace Akers. At North British Station Hotel, Edinburgh, 7.30 p.m., February 23.

*SOUTH WALES BRANCH*

**Annual General Meeting.**—At Britannic House, Llandarcy, 5.30 p.m., February 7.

**Reminiscences of Twenty-eight Years in the Oil Industry.**—E. Thornton. At Britannic House, Llandarcy, 5.30 p.m., March 2.

*STANLOW BRANCH*

**Production and Purification of Low Molecular Weight Olefins.**—H. Steiner. At Grosvenor Hotel, Chester, 7.15 p.m., February 15.

**The Role of the Process Engineer in the Petroleum Refinery.**—C. C. Wuth. At Grosvenor Hotel, Chester, 7.15 p.m., March 15.


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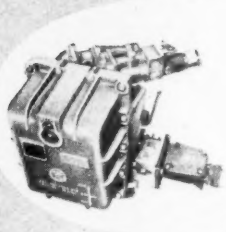

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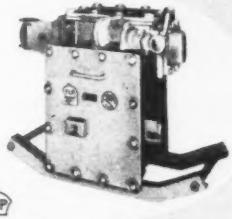

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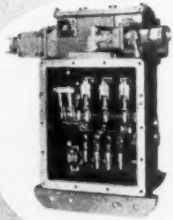

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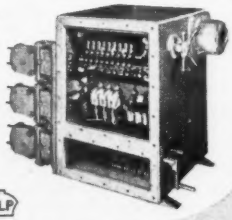

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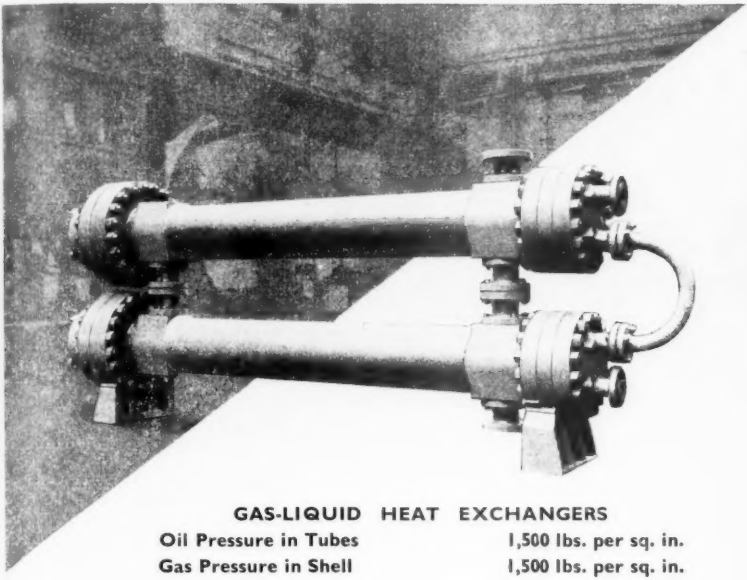

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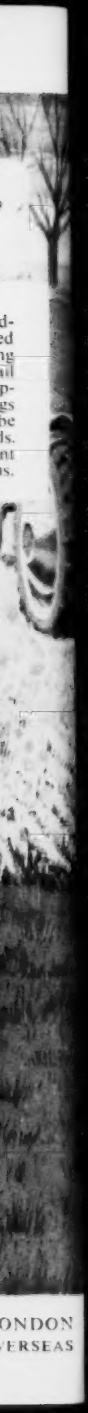

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